Proceedings of the 19th CIRP Design Conference – Competitive Design, Cranfield University, 30-31 March 2009, pp116

Using a Process Knowledge Based CAD for a More Robust Response to Demands for Quotation

L. Toussaint[12], S. Gomes[1], J.C. Sagot[1]

[1]SET Laboratory, team ERCOS, Université de Technologie de Belfort-Montbéliard, 90010 Belfort CEDEX, France

[2]MarkIV Systémes Moteurs, Z.A. Les Grands Prés N°6, 68730 Orbey, France

Luis.toussaint-manuel@utbm.fr

Abstract

Out of 100 hours of engineering work, only 20 are dedicated to real engineering and 80 are spent on what is considered routine work. To accelerate these routine processes, our research is based on methods and tools to capitalize and reuse knowledge in collaborative conception. To validate our research hypotheses, a series of experiments through a design process, with the aid of a Product Lifecycle Management (PLM) tool and a geometric modeler, have been implemented. This article defines a methodology for design and verification of a concept through the use of a knowledge capitalization and its application.

Keywords:

Concurrent engineering, design for manufacturing (DFM), knowledge capitalization.

1 INTRODUCTION

Designing a product, from the definition of the client's needs right up to its fabrication is a process that requires time, attention and the capitalization of data, information, knowledge [3] and experiences gathered from previous projects [5][11]. This knowledge is kept by a limited number of people, usually called 'Experts' and is not necessarily capitalized in a practical, reusable way, which can be translated into a loss of time and a delay for the projects. Engineering research in knowledge management and feedback information becomes essential to improve productivity and responsiveness during the design phase. This article focuses on developing methods of collaborative design, based on product-process knowledge, to expedite the repetitive processes of engineering. The idea behind this is to enable experts to gather their knowledge gained from previous engineering experiences and store them in an interactive and intuitive database. This database will allow designers to apply subsequent manufacturability analyses from the beginnings of the response to demands for quotation phases. The results of these analyses will allow the user to comply with all the domain's rules of the trade (companies manufacturing constraints, process constraints, standards, etc.).

Between 60% and 80% of components used in products manufactured by OEMs are subcontracted [10]. Companies must bring together experts from several areas to check the manufacturability of the components from the earliest stages of conception. Nevertheless, the unavailability of experts makes this approach ineffective and leads to delays and additional costs. The integration of business rules relating to manufacturing constraints, costs and materials could improve the efficiency of designers by incorporating the concept of design for manufacturing (DFM) in their work. The integration of a flexible DFM verification tool would allow the continuous employment of the experiences of experts with the possibility of continuous updating and adaptation in a case-by-case scenario. As a result, the designer can recover all the manufacturing data related to his concept and transmit it to his supplier in a minimum amount of time and keep track of project specifics for future reuse.

2 EXPERIMENTATION WITHIN AN INDUSTRIAL PROJECT

These assumptions were tested out within the research department of a Tier 1 supplier of the automotive industry. The research work proposed in this article is positioned in a scientific context where the ultimate goal is to generate semi- automatic, robust and optimized product models, respecting all knowledge information related to their manufacture gathered from project summaries [11] and expert know-how [5]. Once identified, this knowledge will offer different sets of optimal parameters (functional and specific) [1] respecting all the rules of the trade, particularly thanks to an interfacing with multi-objective deterministic and/or meta-heuristic optimization tools [13] [3]. These sets of parameters can then be transcribed in a parametric three-dimensional CAD model set that will be able to semi-automatically generate several different optimal geometries (solutions on the Pareto frontier), respecting the knowledge retained by the enterprise.

3 PROPOSED METHODOLOGY

For the proper implementation of such an approach, some functional requirements are needed to enable it to be as generic as possible:

1. *Assess the technical feasibility for every new concept.* We have to verify the manufacturability of the concept by the chosen means of industrialization.
2. *Submit an efficient and effective feedback loop for manufacturability problems*. The usage of an interactive verification tool will enable the designer to identify possible problems related to the manufacturability of his concept (unmolding, underdrafts, ill-balanced pieces, constant thickness, etc.). By identifying the possible problems, this feedback will correct or update the concept to adapt it to the means of production planned.
3. *Allow experts to store their rules and knowledge with a minimum of effort and time*. The tool should enable different experts to identify and stock their rules of the trade in a simple and fast manner to facilitate future

project developments.

4. *Under the existing trade rules, allow the analysis of manufacturability at various stages of design*. The design of a product passes through different stages according to the internal organization of each company: Project proposal (responding to a demand for quotation and then launching the project in case of a success), the project (the design of the project, the development of prototypes, the industrialization and the proof of concept) and the manufacturing stage (supply, production and final delivery). The ultimate goal is not to restrict the analysis only to the response to demands for quotation phase, but to apply it throughout the whole design process [16].

3.1 Knowledge capitalization – KNOVA[1] lifecycle

The first part of the methodology starts with the application of Serrafero's knowledge acquisition methodology [12]. This methodology describes the process of transforming a company's tacit knowledge into a properly framed knowledge summary, comprising knowledge in five levels of granularity:

- the **line of work** of a company (e.g.: Automotive manufacturing), decomposed into several knowledge fields (e.g.: plastics, sheet metal, machining...),
- a **field** (e.g.: plastics) composed of several knowledge domains (e.g.: injection, extrusion...),
- a **domain** (e.g.: extruded air conducts, injected air intake manifolds...) decomposed into several knowledge proficiencies (e.g.: design of extruded air conducts, design of their manufacturing processes...),
- a **proficiency** (e.g.: design of extruded air conducts) is decomposed into several specific knowledge (e.g.: the equivalent section area of an air conduct). Proficiencies constitute the different knowledge summaries in a company.
- a **specific knowledge** (or **cogniton**) is the elementary component of a knowledge compendium.

The KNOVA methodology goes through several steps, the '10C's': **c**reation, **c**apitalization, **c**ategorization, **c**onsulting, **c**ompletion, **c**oherence, **c**onsensus, **c**ohesion, **c**ondensation and growth, that allow for the proper gathering and storing of a company's knowledge and know-how. Through the use of knowledge summaries, knowledge can be later on digitalized into a Product Lifecycle Management (PLM) tool where they can be called up to perform automatic verification functions.

3.2 Product/process knowledge capitalization

The context for the application of this methodology requires the use of a collaborative engineering tool style PLM, an evolution of PDM (Product / Process Data Management) style tools [1]. The tool chosen for our work is the Project Monitoring Cooperative Workshop (in french '*Atelier Coopératif de Suivi de Projets*' – ACSP). This Web environment has been developed at UTBM since 1996 to enable synchronous and asynchronous cooperation between the various members of a project [4][6].

The main feature of the ACSP system is its data, information and knowledge management capabilities. Indeed, the ACSP allows them to be capitalized in order to disseminate, share and reuse them [1]. Moreover, this knowledge can be exported in the form of exchange files (Extensible Markup Language - XML) and then used by other software such as MS Excel and CATIA V5 (via scripts).

Expert product/process rules issuing from the KNOVA methodology can be capitalized into the PLM tool and reused for designing a new product. The definition of roles of ACSP, using a multi-domain multi-views approach (Project / Product / Process / Activities) [14] allows experts to transcribe their knowledge and users to operate independently during the next steps of the methodology.

The use of the PLM tool also allows the storage of functional specifications of each product, by filling various associated parameters and indicators (strength, cost, etc.) as well as the results of the various phases of

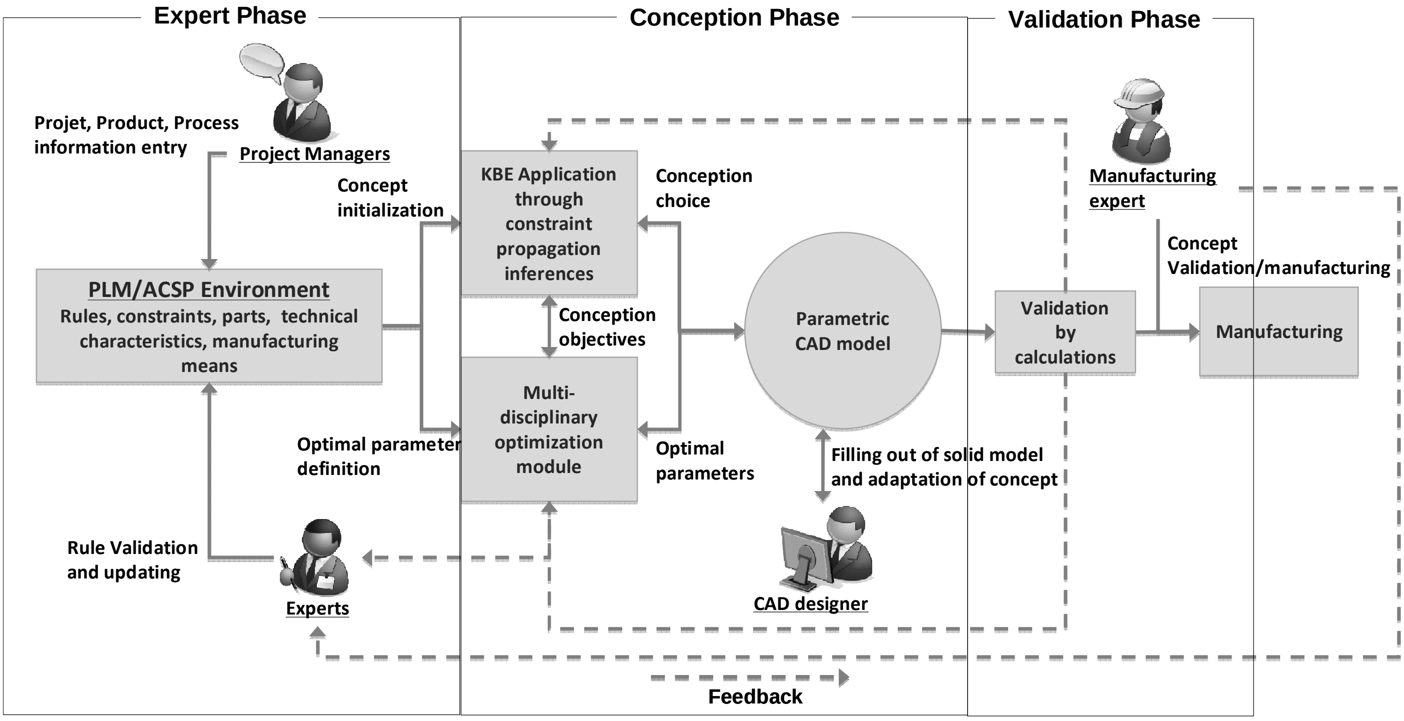

Figure 1. Knowledge reutilization methodology principles - managing knowledge

[1] **Kn**owledge **V**alorization and **A**cquisition

product design such as calculations, modeling, testing or the manufacturing process (Fig. 1). The various actors involved in the project must update all information belonging to each product all along its conception. The classified storage of design specifications on the design/process database, along with a permission to modify system, facilitates their subsequent exploitation in all the concerned stages of design [15].

3.3 Design-verification-validation loop

During his creative phases, the designer must take into account many rules set by different experts. During early design stages, the ability to verify the compliance with each of these rules becomes very important. Success is defined by the company's capacity to generate a product that meets the specifications of the customer and is simultaneously in line with the different trade rules established by the company, according to the manufacturing process chosen.

The semi-automatic verification of the choice of design through the export of knowledge in the form of scripts and its implementation in the CAD software (for example CATIA V5) can reduce design time dedicated to human verification by the designer and the expert. This routine process is amplified when the expert and designer do not share the same geographical location or the same workload [7].

Using a database to identify the various indicators of each product the designer can, during this design-verification-validation loop, find the critical values and exploit them. This operation is done with the CAD software chosen, using the "expert rule" in the form of a script and the critical values for each parameter established in the functional product specifications. This step establishes a feedback loop that furnishes the current product database throughout its lifecycle.

```
    MsgBox "Fibre Choisie"
    Selection.Clear
'Assemblage
    ChoixSurface = True
    Do While (ChoixSurface And Not ChoixFibre)
        Selection.Clear
        MsgBox "Selectionnez la surface (ensem
'Selection de Surface
        InputObjectType(0) = "AnyObject"
        Status = Selection.SelectElement2(Inpu
        If (Status = "Cancel") Then
            Selection.Clear: Selection.Delete
            oPart.Update
            Selection.Clear
            Exit Sub
        ElseIf (Status = "Undo") Then
            ChoixFibre = True
        Else
            If (Status <> "Redo") Then Set Sel
            Set oHSA = SelectionSurface
            oPart.Update
```

Figure 2. Expert rules in script form.

4 INTERACTIVE VERIFICATION METHODOLOGY

A practical implementation of expert rule verification requires the interaction of different actors responsible for the design of a product. The product design leader, responsible for the functional design of the product, defines the individual characteristics according to the specifications requested by the client and the knowledge generated from experience in terms of materials, components, etc. Then the various operations necessary for manufacturing, as well as the general architecture of the product, are defined.

Once the manufacturing operations are chosen, several knowledge and business rules are defined for the new product.

Geometrical rules like heights, thicknesses or interference between parts coming from the customer's specifications, the choice of manufacturing process or internal recommendations of the research department come into play and their values, predefined by the experience feedback loop (Fig. 1), can be recovered using the database and the PLM tool.

The next step carried out by the designer is to start modeling the desired product with his CAD software. During this stage we can draw on other geometric modeling methodologies to better manage the concurrent and knowledge-based functional design of the product [1]. The methodology used adds a preliminary step to the geometric modeling to establish a product architecture (skeleton based modeling) linked by parameters, which guarantees a better monitoring and subsequent modification of the 3D model.

However, all the parameters identified for the product cannot be predefined beforehand. Depending on the characteristics of the product to manufacture, there are parameters that can be modified (see ignored) by choice of the designer without the 3D model being necessarily bad or wrong. By exporting their settings and then using a script linked to an expert rule (Fig. 2), the designer may, at any time, verify the compliance of his concept with these rules and justify his choice in case of deviation.

In the case of an air intake circuit for a car engine, the clients' functional specification establishes the length of the line, the amount of fluid to transport and its speed and a footprint or size to comply to. Due to the evolving nature of car engines, all these parameters cannot be defined beforehand, but they can be verified *post fact*.

After the definition of the path and general shape of the line, the designer can export the customer's needs from the PLM in the form of a script (Figure 2), which will enable him to verify that his concept properly responds to the constraints imposed. Using some basic geometries (generic models) the script verifies the concept, identifies relevant information, compares it with the prior values in the functional specifications and collects the results to be exploited later.

The results allow the designer to validate that his 3D model meets the demands requested (or locate possible errors) and, in case of deviation, they provide evidence to justify the reasons for his choice (for example, the path of a conduit with its section areas, figure 3). The advantage of this method is that it allows the designer to instantly check his work and complete the archives of the product with the direct result of his design choices. These archives will later serve to save time when making design decisions and when reviewing the manufacturability analysis of a new product.

4.1 CAD Analysis

The singularity of this verification methodology is that it processes the geometrical form of the products analyzed. The analysis does not pertain exclusively to features, as there is already research work making headway into this venue [8]. In regards to this research, this translates into knowledge rules being made about the forms of the different products to be analyzed and geometrical analysis being performed to verify these rules.

This analysis can result in a color coding of the product currently being analyzed, depending on if the breach of the rule needs to be corrected or if it stands to function as an accepted deviation.

5 CONCLUSION AND PERSPECTIVES

This experiment allowed the R&D department to accelerate the finalization of the first steps of response to demands for quotation on several products and identifying possible complications in downstream stages of the design process. This shows the importance of an ongoing verification as well as the importance of capitalizing the knowledge used in various projects that are carried out.

Reducing the number of verifications made by the experts during the early stages of design can increase the responsiveness of the R&D department as well as reduce the time dedicated to routine activities. It is recognized that 80% of time spent in an R&D dept. is dedicated to routine activities, against 20% dedicated to innovation [9]. Using a knowledge database and semi-automatic tools included in the PLM will enable us to consider dividing this routine work time by two [2].

This time saved can be invested at all stages of product design, providing a reliable and robust result with minimal iterations and validations necessary.

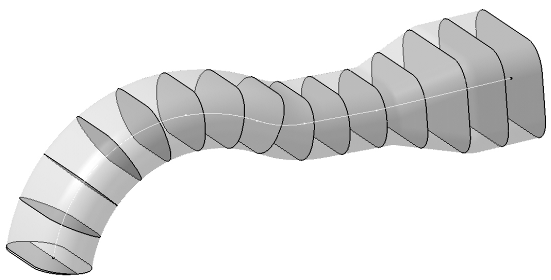

Figure 3. Air conduct analysis by semi-automatic script.

This principle opens up several interesting perspectives, already mentioned in [3], with implications in the domain of generation and semi-automatic verification (Verification Phase, Figure 1), in a parametric geometrical CAD tool (CATIA V5, NX6, etc.) incorporating rules of engineering. These rules are extracted and driven directly from a functional specification and a project record in the PLM tool.

For the moment the KNOVA methodology is being used to develop knowledge summaries of the different products manufactured by the company where the research is being made. If this investigation bears fruits they will be used to further the development of the methodology proposed in this article. If not, the KNOVA methodology will be revised and a proposition for a different one to follow will be subsequently made to the company. This will be done in order to find a methodology that will be perfectly tailored to the company and products in hand.

6 REFERENCES

[1] J.B. Bluntzer, S. Gomes, J.C. Sagot, 2006, Application de la modélisation CAO à base de connaissances à la conception fonctionnelle, collaborative et multi sites de produits modulaires, Colloque francophone sur les sciences de l'innovation, CONFERE 2006, 06-07 July, Marrakech, Maroc.

[2] N. Gardan, Y. Gardan, 2003, An application of knowledge based modeling using scripts, Expert Systems with Applications.

[3] S. Gomes, J.C. Sagot, 2002, A concurrent engineering experience based on a cooperative and object oriented design methodology, In Best Paper Book, 3rd International Conference on Integrated Design and Manufacturing in Mechanical Engineering, Dordrecht, Pays Bas, pp.11-18.

[4] S. Gomes, J.C. Sagot, A. Koukam, N. Leroy, 1999, ACSP an intranet forum supporting a concurrent engineering design life cycle, 6th European Concurrent Engineering Conference, ECEC'99, Erlangen-Nuremberg, 21-23 April, pp. 249-251.

[5] M. Grunstein, 2007, GAMETH : un cadre directeur pour repérer les connaissances cruciales pour l'entreprise, MG Conseil, February 2007.

[6] D.T. Liu, X.W. Wu, 2001, A review of web-based product data management systems, Computer in Industry, 2001, 44, 251-262.

[7] C.K. Mok, K.S. Chin, H. Lan, 2008, An internet-based intelligent design system for injection moulds, ScienceDirect, 2008.

[8] G. Molcho, Y. Zipori, R. Schneor, O. Rosen, D. Goldstein, M. Shpitalni, 2008, Computer aided manufacturability analysis: Closing the knowledge gap between the designer and the manufacturer, CIRP Annals – Manufacturing Technology, 2008, 57, 153-158.

[9] B. Prasad, 1996, Concurrent engineering fundamentals, Vol. 1, Prentice-Hall, Englewood Cliffs, 1996.

[10] M. Rezayat, 2000, Knowledge-based product development using XML and KCs, Computer Aided Design 2000.

[11] P. Serrafero, S. Gomes, D. Bonnivard, L. Jezequel, 2006, De la mémoire projet à la compétence métier: vers la synthèse de connaissances métier en ingénierie robuste des produits/process, International Conference on Integrated Design and Manufacturing in Mechanical Engineering, IDMME '06, May 2006.

[12] P. Serrafero, 2003, Cycle de vie, maturité et dynamique de la connaissance : des informations aux cognitons de l'Entreprise Apprenante, Revue ENSAM, April 2003.

[13] B. Sid, M. Domaszewski, F. Peyraut, 2005, Topology optimization using adaptive genetic algorithm and new geometric representation, OPTI '05, Ninth Int. Conf. on Computer Aided Optimum Design in Engineering, WIT Press, pp. 127-135, 2005.

[14] S. Tichkjewitch, E. Chapa Kasusky, P. Belloy, 1995, Un modèle produit multi-vues pour la conception intégrée, Congrès international de Génie Industriel de Montréal - La productivité dans un monde sans frontières, Volume 3, pp. 1989-1998.

[15] C. Yang, M. Yu, 2006, A study on product knowledge management method supporting product agile customized design, International Conference on Integrated Design and Manufacturing in Mechanical Engineering, IDMME 2006, Grenoble, 17-19 May.

[16] Z. Zhao, J. Shah, 2005, Domain independent shell for DFM and its application to sheet metal forming and injection molding, Computer-Aided Design, Sept 2005.